HARBORVIEW INJURY PREVENTION AND RESEARCH CENTER
HARBORVIEW MEDICAL CENTER

Harborview Injury Prevention & Research Center at University of Washington

CIREN Program Report

Introduction

Motor vehicle related injuries are the main cause of death and disability among children and young adults in America. Much has been accomplished to address this problem over the past 30 years, since the National Highway Traffic Safety Administration was created. However, much remains to be done. The Seattle CIREN team believes that our work has been assisting with the development of a safer America and helping to lower the rates of death and disability from automotive crashes through three main mechanisms:

- Surveillance and vehicle design feedback;
- Basic research;
- Outreach activities.

Each of these will be considered in turn.

Surveillance and Vehicle Design Feedback

A basic mission of the entire CIREN project has been to gather information on how automotive safety improvements and related standards have been performing in the real world. Crash tests employing anthropomorphic test devices (ATDs or more commonly known as “crash test dummies”), although very useful, have significant shortcomings in being able to provide all the information necessary for automotive safety design. Hence the CIREN network was created to provide additional information. It is designed to analyze real-world crashes and to provide feedback for possible design and related motor vehicle safety standards modifications. It may also function as a surveillance system to help detect or provide additional information about unexpected field issues, such as the recently publicized problems with airbag-related injuries to children.

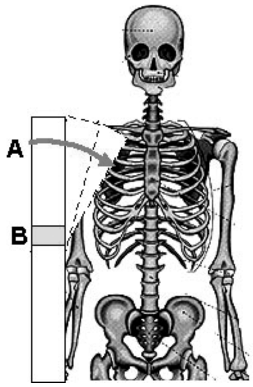
The Seattle CIREN team has been contributing cases to the overall CIREN database for these purposes. To date we have gathered information on 290 cases. A few brief examples will be considered. Airbags have been required in front passenger positions for protection in frontal crashes. Some late model vehicles have begun installing side airbags to improve protection in side impacts. The potential effectiveness of these side airbags has yet to be documented in real world crashes. The Seattle CIREN team has investigated several crashes in which such side airbags deployed (Figure 1, page 48). Valuable information on the performance of this new safety technology has been included in the CIREN database, for review by NHTSA and the automobile manufacturers.

In addition to individual safety technologies, CIREN provides information on performance of Federal Motor Vehicle Safety Standards (FMVSS). For example, FMVSS 214 was created to provide increased protection for occupants in side impact collisions. The standard was originally created to take into account a passenger vehicle striking the side of another passenger vehicle. This was the most common scenario in side impacts in the early 1990s. However, in recent years the American vehicle fleet has changed with an increase in the numbers of light truck vehicles (LTV), such as pick-up trucks and sport utility vehicles. As a consequence, many side impact collisions now occur between these LTVs and smaller passenger vehicles. The result is that the FMVSS 214 mandated reinforced side impact protection is often overcome by the greater vehicle mass and higher bumper frames of the LTVs. The net effect is an increase risk of serious injury to the passengers of the smaller passenger vehicles, as is demonstrated in Figures 2 and 3 (page 48).

Figure 1. Side airbag that deployed in a crash. CIREN investigations allow analysis of the effectiveness of such new safety technology

In similar fashion, the mismatch of frame heights between LTVs and passenger vehicles leads to an increase risk of injury in frontal crashes. In these, the higher LTV bumper frames often override the frames of the passenger vehicles. The protection provided by the passenger vehicle frames are thus bypassed, with a resulting increase in the propensity for longitudinal intrusion of the instrument panel and an increase in the risk of serious injury to the passengers. This is shown in Figures 4 and 5 (page 49). Such mismatch in bumper frame heights also results in an under-ride being experienced by the LTVs. The lower bumper height of the passenger vehicle may result in intrusion of the LTV toe pan, with increased risk of foot and ankle injuries to the LTV occupants. This is shown in Figures 6 and 7 (page 50).

Figure 2. Side Impact Protection in a Typical Passenger Car



Point B indicates the usual height of side impact protection mandated by FMVSS 214. This height provides significant protection against side impacts by other passenger vehicles. However, the bumper frames of light truck vehicles, such as sport utility vehicles and pick up trucks, are usually located higher (Point A). In side impacts of light truck vehicles into passenger cars, the mandated side impact protection is often overcome due to such mismatch, resulting in a high risk of severe chest injuries to the occupants in the passenger vehicle.

Figure 3. Photo of Side Impact Collision of Sport Utility Vehicle into a 1998 Passenger Vehicle

The side impact protection in the passenger vehicle door was overcome by the higher bumper frame of the sport utility vehicle. This is demonstrated by the intrusion of the upper portion of the door. Such intrusion results in a significant risk of severe chest injury.

Figure 4. External View of Passenger Car Involved in Frontal Offset Crash

Frontal offset impact showing mismatch and override of the vehicle frame of a passenger vehicle (shown here) by the higher bumper frame of a light truck vehicle. The white rectangle indicates the position of the bumper of the light truck vehicle.

Figure 5. Interior of the Vehicle Seen in Figure 4.

The bumper frame height mismatch and override resulted in significant intrusion of the instrument panel and consequent lower extremity injuries.

Research

In addition to the individual case reports which our CIREN center provides for the surveillance and vehicle design feedback noted above, we have been undertaking research on larger numbers of crashes and drawing inferences that may be useful in the overall approach to vehicle safety. Several projects are underway. We report here several that have reached publication. These include both publications that have specifically employed CIREN cases, as well as those that have employed other data sources, based on ideas generated from CIREN case reviews at our center. All of these studies provide information that helps us better understand how people get injured in crashes and hence how we can better prevent such injuries.

A. "Effectiveness of automatic shoulder belt systems in motor vehicle crashes." Frederick Rivara, Thomas Koepsell, David Grossman, Charles Mock. *Journal of the American Medical Association*, Vol 283, pg. 2826-2828, June, 2000.

The automatic shoulder harness was originally envisioned as a means by which occupants would have automatic shoulder restraints without having to remember to take the action of buckling up. However, the successfulness of the safety technology was lessened by the fact that many people regarded the shoulder harness as sufficient protection and did not take the action of buckling up their manual lap belt. Reports on the effectiveness of the shoulder harness alone had been mixed in prior research. The effectiveness of the shoulder harness alone is of significance in that approximately 10 million cars with automatic shoulder belt systems are currently in use in the United States. Anecdotal report from our own CIREN database suggested that shoulder harnesses alone were in fact of low effectiveness at preventing injuries. We set out to determine this more scientifically by analyzing over 25,000 crashes in the 1993-1996 National Highway Traffic Safety Administration Crashworthiness Data System (CDS).

We looked at the main outcome measures of death and serious injury and compared them for occupants in frontal crashes using the varying forms of restraints: lap and shoulder belts together, automatic shoulder belt without lap belt, and no restraint use.

This research showed that automatic shoulder belts with lap belts lowered the risk of death by 86% compared to use of no restraint alone. Use of automatic shoulder belts without the lap belts, however, resulted in a lesser (34%) decrease in mortality. Moreover, use of the automatic shoulder belt alone without lap belts was associated with a two fold increase in the risk of serious chest or abdominal injuries.

The study concluded with a call for increased awareness of this problem and for increased efforts to alert the public to the need to use lap belts along with automatic shoulder harnesses.

B. "The relationship between body weight and risk of death and serious injury in motor vehicle crashes." Charles Mock, David Grossman, Frederick Rivara, Robert Kaufman, Christopher Mack. *Accident Analysis and Prevention*, 34: 221-228, 2002.

Anecdotal reports from our CIREN database suggested that heavier occupants were at an increased risk of injury and

Figure 6. External View of SUV Involved in Frontal Offset Impact

Offset frontal impact in which the pictured sport utility vehicle (SUV) with a higher bumper frame collided with a passenger vehicle with a lower bumper frame. This resulted in an impact to the tire/axles below the SUV bumper frame.

Figure 7. Interior of the Vehicle Seen in Figure 6.

The impact with the tire/axle of the lower passenger vehicle forced the front left tire of the sport utility vehicle (shown here) into the floor and toe pan of the driver position. This resulted in severe bilateral foot fractures. The intruding front left tire of the sport utility vehicle is outlined in white.

death in motor vehicle crashes. There had been smaller studies in the literature suggesting that this may indeed be the case. However, these studies looked at the effect of weight on a variety of different types of mechanisms of injury but not specifically focusing on automobile crashes.

We set out to evaluate the question on a larger scale and more specifically for automobile occupants. We evaluated data on 27,263 occupants in crashes from the 1993-1996 National Highway Traffic Safety Administration Crash Worthiness Data System. We compared the likelihood death and serious injury by different categories of weight. We showed an increased risk of death with increased body weight. Compared to occupants who weighed less than 60 kg (132 lbs) occupants who weighed 60-99 kg (133-219 lbs) were 93% more likely to die. Occupants who weighed 100-119 kg (220 – 263 lbs) were 157% more likely to die and occupants who weighed over 120 kg (over 264 lbs) were 348% more likely to die. This increased risk of death may, in part, be due to increased medical problems among those who are more over-weight. However, the study also showed an increased likelihood of sustaining severe injuries with increasing weight. These findings persisted even after adjusting for differences in vehicle curb weight, seating position, restraint use, occupant age and gender. The implication of these findings is that heavier occupants' weights may need to be taken into consideration in the future in vehicle safety design.

C. "Femur Fractures in Relatively Low Speed Frontal Crashes: The possible role of muscle forces." By A Tencer, R Kaufman, K Ryan, D Grossman, B Henley, F Mann, C Mock, F Rivara, S Wang, J Augenstein, D Hoyt, B Eastman. *Accident Analysis and Prevention*, 34: 1 – 11, 2002.

The setting of motor vehicle safety standards and the determination of safety ratings of vehicles (e.g. The New Car Assessment Program) have depended on background information on injury thresholds. These thresholds represent the probable force that can be tolerated by the human body and above which injury typically occurs. For example, in frontal crashes, it has been generally accepted, based on cadaver research, that the human thigh can tolerate, on average, 8900 Newtons (2000 lbs) in compression along its axis before a femur fracture occurs. The validity of this estimate has not been well substantiated in actual crashes.

We set out to determine the actual forces required to fracture a femur from the data collected from CIREN crashes. We studied a group of relatively low speed frontal collisions (mean collision speed change of 40.7 kph or 25.4 mph) in which the only major injury suffered by the partly or fully restrained occupant was a femur fracture. However measurements from tests using crash dummies in similar vehicles at greater speed changes (mean of 56.3kph or 35.2 mph) showed that in almost all cases, the femur should not have fractured because the measured loads were below fracture threshold.

In order to explain the fractures that we observed, the loads in the femurs of the occupants in our crash sample were estimated and compared to recognized femur fracture thresholds (derived from previous cadaver research). Femur loads in the crashes we studied were estimated by inspecting the scene and measuring crush deformations in each vehicle, defining occupant points of contact and interior surface intrusion, and calculating crash change in velocity (delta V) and deceleration. Measured femoral loads in crash dummies from test data in comparable vehicles were scaled to the crashes in our sample by adjusting for differences in crash deceleration, occupant weight, and restraint use.

All the 20 occupants in our sample sustained at least a transverse midshaft fracture of the femur with comminution (multiple fragments), which is characteristic of axial compressive impact, causing bending and impaction of the femur. However, the average estimated femur compressive load was 8187N (1,840 lbs), which is below the generally accepted threshold of 8900N (2000 lbs). Moreover, based on the previous cadaver tests, the average probability for fracture in our study was only 19%. In fact, in 13 crashes the fracture probability was less than 10%.

Two factors we propose might explain the discrepancy. The occupant's femur was out of position (typically the driver's right foot was on the brake) and did not impact the knee bolster, instead hitting stiffer regions around or on the steering column. The knee bolster is the region of the dashboard designed to absorb knee impact when the occupant is sitting, as would a crash dummy, with both legs forward and both feet on the floor, not with the right leg angled and the foot on the brake. Additional compressive force on the occupant's femur probably resulted from muscle contraction due to bracing for impact. Adding the estimated internal load on the femur from muscle contraction to the estimated external load from knee to dashboard impact, increased the femur loads beyond threshold, explaining the fracture in all but one case.

Since crash tests using dummies do not simulate out of position knee to dashboard contact or muscle contraction loading, they may underestimate the total loads acting on the femur during actual impacts where the driver is avoiding and bracing for the crash. These results may have implications for altering knee bolster design to accommodate out of position knee to dashboard contact and the internal compressive loads caused by muscle forces from bracing.

D. "Are Drivers More Likely to Injure Their Right or Left Foot in a frontal Car Crash: A Crash and Biomechanical Investigation." M Assal, P Huber, A Tencer, E Rohr, C Mock, R Kaufman. In *Proceedings of the 46th Meeting of the Association for the Advancement of Automotive Medicine*, Tempe, AZ, October 2002.

Extremity injuries, although not generally life threatening, are a major source of disability after motor vehicle crashes. This is especially the case for fractures and dislocations involving the feet and ankles. Factors which contribute to these injuries and which can be manipulated to lower the risk and severity of such injuries are not well understood. In this study, we wished to determine what factors relating to foot position and use of brake pedals might contribute to foot injuries. We hypothesized that for frontal crashes, the driver was more likely to sustain foot injury than the front seat passenger. Likewise, we hypothesized that the driver's right foot was more likely to be injured than the left because that right foot was likely positioned in dorsiflexion and eversion during the crash and hence less able to tolerate crash forces. If drivers were more likely to sustain injury, it might result from the drivers' foot being pressed against the brake pedal during the crash, medial to the knee, forcing the foot into eversion combined with dorsiflexion. If this were the case, the threshold force of the foot to injury in eversion combined with dorsiflexion should be considered. Currently available data on foot threshold is based on dorsiflexed position alone. Therefore, we addressed two questions: (1) are drivers who are braking during a crash more likely to injure their right (possibly everted) foot; and (2) does the everted and dorsiflexed foot have a different force threshold than the dorsiflexed foot?

Data were utilized from several sources, including CIREN, NASS, and biomechanical laboratory tests. Seventeen Seattle CIREN frontal crashes in which there was a significant tibial shaft, ankle or foot injury were studied. The majority (16 / 17) were drivers and most (13/17) had injured their right lower extremity. The distribution of injuries were: fibula fractures (8), calcaneus fracture (3), malleolus fracture (3), and talus fracture (4). This component of the study provided preliminary evidence to support the study hypothesis.

Next, data from NASS were utilized to provide an epidemiologic perspective. A total of 26,168 occupants fit the study criteria. In total, 1.3% of occupants had a serious foot/ankle injury. Such injuries were more common among drivers (1.4%) than among front seat passengers (0.7%). The difference was almost exclusively due to a higher risk of right-sided injuries among drivers. These were 2.6 times as likely for drivers as passengers. The action of braking seemed to play a role. In cases with toe pan intrusion of 15 cm or more, drivers who were braking were twice as likely to sustain a foot/ankle injury (18%) as were drivers who were not braking (9%). Such injuries were also primarily right sided.

Finally, in the biomechanics laboratory, nine matched pairs of cadaveric feet were tested in compression with one in dorsiflexion, and the other in dorsiflexion and eversion. There was a significant decrease in load to failure between specimens forced into dorsiflexion and eversion (mean 4107 Newtons) compared with dorsiflexion alone (mean 6468 Newtons). The dorsiflexion alone data were similar to that reported in the literature, indicating that foot position, and not a different sample, accounted for the lower threshold force for dorsiflexion and eversion.

Implications of this work are that if thresholds based on data from dorsiflexion and compression loading are used to predict foot and ankle injury in frontal crashes, they may not represent that population of drivers who are braking at the time of the crash and who could suffer injuries at forces lower than current threshold values. Moreover, brake design and resulting foot position at the time of frontal crash may be a useful safety feature to evaluate further.

E. "Correlation of head injury to vehicle contact points using Crash Injury Research and Engineering Network (CIREN) data." Nirula R, Mock CN, Kaufman R, Rivara FP, Grossman D. *Accident Analysis and Prevention,* 2003 Mar;35:201–10.

Head injury is one of the most common causes of death in automotive crashes. It is also a common cause of long-term disability. Such deaths and disability occur despite optimal use of existing treatment capabilities. Hence, prevention emerges as a key element in our efforts to decrease the toll of head injury. Efforts to improve vehicle design, which minimize forces exerted to the occupant's head, may lead to a reduction in the frequency and severity of head injury. We set out to identify mechanisms producing severe head injury in motor vehicles crashes derived from the CIREN database. From the Seattle CIREN database, we compiled 15 cases with severe head injury (abbreviated injury score of 4 to 6) from 1997 to 1998. For these cases, we examined crash mechanism, energy transfer, point of head contact, vehicle intrusion, and resulting injuries.

The injuries were primarily due to side impacts (n=10) in comparison to frontal crashes (n=5). The average net change in velocity (delta V) was 15 miles per hour. In cases where the primary point of head contact could be elucidated, the B-pillar predominated (4 cases, 33%) followed by striking external objects (2 cases, 17%). The following structures each was associated with one case (8%): A-pillar, C-pillar, roof side rail, windshield header, windowsill, and airbag.

In this series, the predominant mechanism of head injury was lateral impacts, especially those in which the victims' heads struck the B-pillar. The need for improved head protection from lateral impacts is indicated. Potential engineering changes to provide such protection might include side airbags and softer, more energy absorbing materials to cover the pillars, especially the B pillar.

Outreach

The Seattle CIREN team, primarily Rob Kaufman, has conducted 80 outreach and training events from January 1999 to October 2002 (See Appendix 1). These have been attended by over 7000 participants, primarily in NHTSA X region. Evaluations have been overwhelmingly excellent. The demand for this knowledge about crash injury mechanisms has been demonstrated by requests for Seattle CIREN staff to return for repeat presentations at many of the major regional safety conferences. Most presentations were given for an hour, and some events were half-day or full-day training sessions.

The Seattle CIREN outreach and training presentations have utilized the crash and medical data from 150 Seattle CIREN cases to help illustrate various crash injury mechanism topics and themes such as: frontal and side impact injury mechanisms, intrusion equals injury, the effectiveness of seatbelts, the demographics of children and the elderly, lower extremity injuries, head injuries, abdominal and thoracic injuries, mismatch vehicle impacts, and rollovers. In addition, much of the outreach content utilizes the above peer reviewed research conducted by the Seattle CIREN center.

The Seattle CIREN tracking data showed that almost a third of the motor vehicle crash victims admitted to the trauma center were between the ages of 15-21 and nearly two-thirds were not wearing seatbelts. This unfortunate fact prompted another Seattle CIREN outreach presentation targeted at high school students and pre-drivers, called "The Force is With You". This program was created to increase knowledge of how injuries occur to occupants who do not wear their seatbelt and hence to reinforce the importance of seatbelts. An evaluation demonstrated an increase in knowledge and improved seatbelt use among nearly 1000 students who had participated in the program. The program recently received national attention after being presented at the American Driver and Traffic Safety Education conference. The response was overwhelmingly positive to the effective approach of utilizing the CIREN crash injury mechanisms data to illustrate the importance of seatbelts. Many driver educators have approached our team to develop this program for distribution nationally since no similar material currently exists.

The following is a list of the target audiences at these outreach events. The diversity of the audiences demonstrates the versatility of utilizing the CIREN data for training and outreach purposes.

Target Audience Listing:

Surgeons/ED Staff/Trauma Nurses/ Airlift nurses

Medics/EMS Fire Rescue at Local, County, State, & Regional levels

Medical Examiners/Coroners

- Engineers/Auto manufacturers
- NHTSA/Government — CIREN Public meetings
- Traffic Safety/Interest Groups
- Public Safety/Interest Groups
- State DOT and Dept. of Health
- Law Enforcement/Reconstuctionist
- Law Enforcement/Officers
- Public / High Schools
- Driver Educators

For physicians and nurses, this has involved discussions of the scientific basis of the CIREN project and how this information is useful to prevent and treat injuries. For paramedics, the emphasis has been training for recognition of exceptionally dangerous crash patterns which should increase the level of suspicion for occult injuries. For traffic police, the emphasis has been improvement in their skills in crash reconstruction with special emphasis on injury-related aspects of the analysis.

The various forms of outreach have been very popular with the target groups with more requests for subsequent sessions than we are able to handle with our staff and budget at this time. We are currently working on the design of pre-formatted teaching modes such as videos and CD-ROMs to increase the reach of these training activities. A selected few of the testimonials that have been received from participants in CIREN outreach programs are listed in Appendix B.

In addition to formal presentations, the training from the CIREN project has been applied on an on-going basis. All of the Advanced Life Support (ALS) ambulance rigs in Seattle and surrounding King County have been supplied with digital cameras to take pictures of the exterior and interior of damaged vehicles in the most severe crash situations. The photographs are brought into the emergency room on floppy disk. These are then viewed by doctors and nurses caring for the injured person. Especially dangerous crash deformation patterns, such as those with high degrees of intrusion, result in increased evaluation and monitoring for occult injuries.

Finally, Seattle CIREN cases have been utilized in nation-wide presentations at public meetings for the entire CIREN network. These are detailed in Appendix 3.

Cross Cutting Issues

The above sections have demonstrated the importance of the work carried out by the Seattle CIREN team in feedback on automotive design; basic research in crash injury causation; and outreach and training. Frequently these approaches are utilized in a combined manner to address major safety concerns, as outlined next.

A. Side impacts of trucks/SUVs into passenger vehicles are increasingly overriding the impact support beams mandated by FMVSS 214, with resulting severe chest injuries.

- Seattle CIREN's use of detailed medical data on crash occupants suggests side impact standards (e.g. FMVSS 214) need to be changed, along with greater harmonization of the bumper frame heights of all vehicles.
- Outreach and training to first responders and trauma care providers has been done to identify these damage patterns, which are directly associated with thoracic injuries.

B. Side impact door panel stiffness and geometry may contribute to serious abdominal penetration and injuries

- Review of Seattle CIREN cases suggested that stiff armrests may be a source of some serious abdominal injuries. The possibility is being evaluated further by epidemiologic research using NASS data and by biomechanics laboratory data. Seattle CIREN bioengineers have also used MADYMO modeling showing the door geometry's and armrest are likely sources of abdominal and thoracic injuries. These studies are preliminarily, suggesting a need to consider the stiffness of arms rests in future research and possibly in safety standards.
- Outreach and training of trauma care providers has been done to assist identification of occult injuries from armrests in side impact collisions.

C. Offset frontal impacts of SUV/trucks into passenger cars are creating serious problems due to the bumper height mismatch.

The override into passenger cars is causing significant passenger compartment intrusion causing serious lower extremity and thoracic injuries. The passenger cars are also under-riding the SUV/truck's bumper with resulting impact into the SUV/truck's front tires. These are then forced into the toe pan, causing serious lower extremities fractures involving the feet of the SUV / truck occupants.

- Seattle CIREN cases have been presented in public forums to draw attention to the problem of bumper height mismatch and hence to show the possible need for changes in related Federal Motor Vehicle Safety Standards.

- First responders and trauma care providers have been trained to identify such bumper height mismatch as a factor associated with increased risk of serious injury.

D. Contact with the B-pillar and to some extent the A and C pillars have been identified by Seattle CIREN research as major sources of head injury, especially in side impacts.

- Individual case reviews have suggested the possible importance of side impact airbags, especially those designed to protect the head.
- The Seattle CIREN bioengineers have shown in MADYMO simulations that a padding of a few inches to the interior surfaces of the pillars might reduce the injury producing forces to the head.
- Even a moderate reduction in the rate of serious head injuries would result in significant savings to society, as each serious head injury is associated with $53,330 in medical costs.
- Outreach and training has been conducted to first responders and trauma care providers on how to identify when a potential for serious head trauma may exist.

Secondary Benefits

The involvement of our center with the CIREN project has resulted in several secondary benefits above and beyond the project itself. These have included the outreach work noted above. They have also included an expanded capacity of our center to understand automotive safety issues and to undertake related research and safety promotion work. Such increased capacity has amplified our center's promotion of the use of child booster seats both in the northwest region and nationwide. This increased capacity has also resulted in garnering of other research funds for related activities. We will conclude with a few words on each example.

Promotion of Child Booster Seats. By better understanding the biomechanics of children in crashes, we have been better able to demonstrate the efficacy of child booster seats. These are seats for children aged 4 – 8 years, who are too big for the usual car seats, but not yet big enough to be properly restrained by adult restraint systems. Prior lack of attention to this age group has resulted in a stagnation in automotive death rates in this age group, while rates of death have fallen for older and younger children. Promotion of booster seats is increasingly understood as a way to overcome this problem. Our center has been demonstrating the efficacy of such booster seats through CIREN case reviews and by computer simulations using MADYMO.

Related Research. CIREN case reviews at our center suggested to us a likely association of stiffer door panels and increased risk of chest and abdominal injuries as shown in

Figure 8. Armrest stiffness and protrusion may result in increased risk of abdominal injuries in side impact collisions.

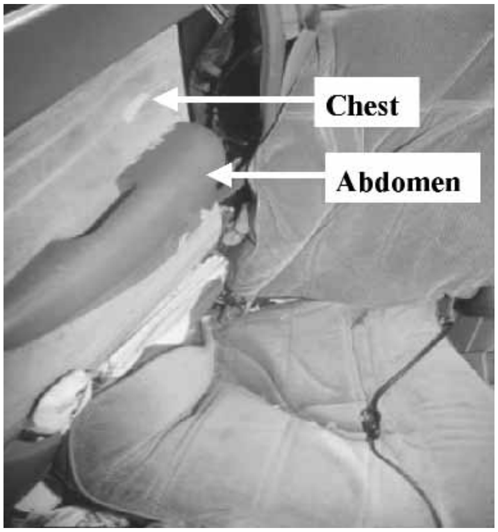


Figure 8. We have pursued this lead by using biomechanical examination of door geometry and MADYMO simulation. Based on such preliminary work, Dr. Allan Tencer of our center has recently been awarded $486,000 from the National Center for Injury Prevention and Control of the CDC for a study on the role of vehicle door interior surfaces during a side impact collision. This study will use modeling and cadaveric testing to: (1) investigate how the occupant interacts with, and document the injuries occurring from contact with the interior surface of actual doors in simulations of side impact crashes, (2) compare the injuries resulting from actual doors with features such as protruding armrests when primary occupant to door contact occurs either at the hip or abdominal regions during impact, and (3) provide additional data to assess the ability of various proposed criteria to predict injury. The results of this research project will hopefully provide insight into how persons of different stature are affected by contact with the door surface during a side impact, how thoracic injuries can result, and whether deformation based, acceleration based, or other injury criteria are the best predictors of injury.

In conclusion, the Seattle team feels that the CIREN project has significantly contributed to our pre-existing injury prevention efforts and hence to a safer America. Through a combination of feedback on the performance of safety technology; through basic research into automotive safety; and through outreach and training, we believe we have contributed to a better understanding of automotive safety and injury causation.

Report prepared by:
Charles Mock & Robert Kaufman
September 27, 2002

Appendix 1

List of Seattle CIREN Outreach Activities: 1999–2002

January 1999 – Oregon State DOT Three Flags Safety Conference

April 1999 – National Trauma Care 99 – Harborview Medical Center

May 1999 – “Coffee Talks” – Harborview Medical Center monthly staff meeting

June 1999 – NHTSA LifeSavers National Conference

July 1999 – Washington State Traffic Safety Commission / Three Flags Conference

August 1999 – Harborview Medical Center Board Meeting

September 1999 – 3rd Annual CIREN Conference, San Diego

October 1999 – Annual Oregon Transportation Safety Conference

October & November 1999 – Harborview Injury Prevention and Research Annual Training.

November 1999 Ford Motor Engineers – Video conference

November 1999 Stanford University – Stanford Medical Trauma Conference

December 1999 – Harborview Medical Center Surgery Department Seminar.

January 2000 – King County Medical Examiners Traffic Conference.

February 2000 – Trauma Care for the New Millennium, Spokane WA

February 2000 – Idaho Office of Highway Safety, Safety Seatbelt Summit.

March 2000 – King County Traffic Coalition Seminar

March 2000 – District 7 of the Washington State Patrol Reconstructionist training.

April 2000 – Harborview Medical Center staff monthly “Brown Bag staff meeting”

May 2000 – NHTSA Region X – All hands Meeting

May 2000 – High School Outreach Project Pilot – “The Force is with you”

May 2000 – Alaska Highway Safety “Buckle up” Seatbelt Summit, Anchorage, AK

April 2000 – HIPRC research seminar on Femur fractures CIREN study

May 2000 – HIPRC research seminar on Air bag technologies with live deployment in parking lot

June 2000 – WA State Law Enforcement Crash Investigator Training, Criminal Training Center.

July 2000 – Idaho Buckle up Seatbelt summit

July 2000 – CIREN public presentation – “Side impacts-Affects of door panel geometry and stiffness”

August 2000 – Annual Washington State EMS and Trauma Conferences

September 2000 – Seattle Medic Tuesday Series Meeting

October 2000 – Oregon Department of Transportation-Annual Traffic Safety Conference

September 2000 – NAME National Association of Medical Examiners conference

November 2000 – Pediatric Grand Rounds at Children’s Hospital

December 2000 – The Force is With You – High School Outreach

December 6, 2000 – Washington State Driver Impaired conference – WA Traffic Safety conference

January 2, 2001 – Harborview Medical Center Paramedic Training

January 10, 2001 – Oregon DOT – Three flags Law Enforcement conference

January18, 2001 – Bellevue EMS medic meeting

Feb 1st, 2001 – Kitsap County EMS monthly training meeting.

Feb 8th, 2001 – Child Safety Technician Regional Update Training, Portland Oregon

March 16th, 2001 – CIREN NHTSA Public quarterly meeting

March 17th, 2001 – Wenatchee EMS North Central Washington EMS conference.

April 10th, 2001 – National Harborview Medical Center Trauma Conference.

April 10th, 2001 – National Harborview Medical Center Trauma Conference Workshops

April 13, 2001 – Harborview Medical Center Thoracic Trauma and Critical Care Conference

April 27th, 2001 – Legacy Emmanuel Trauma Center, Portland Oregon

April 28th, 2001 – Mount Vernon – Northwest Washington State EMS conference

May 18th , 2001 – Alaska Buckle Statewide Seatbelt Summit

May 29, 2001 – Pierce County EMS Training Conference

June 5, 2001 – Law Enforcement Crash Investigator Training, Criminal Justice Training Center

June 11, 2001 – Trauma Surgeon Meeting

June 20, 2001 – CIREN NHTSA Public Meeting – Theme- "Getting the word out – CIREN"

July 11, 2001 – City of Eugene Oregon Medic and Fire Rescue Training

July 20, 2001 – Washington State Patrol Technician Training

August 15, 2001 – Airlift Northwest Flight Nurses training

September 6, 2001 – CIREN NHTSA Public Meeting – Theme- SUV's

September 2001 – Idaho Buckle up Seatbelt summit

October 22, 2001 – Alaska DOT – Transportation and Technology conference, Anchorage AK

October 26, 2001 – Oregon Department of Transportation Traffic Safety Conference

November, 2001 – Alaska statewide EMS Symposium training

Dec 4-6, 2001 – NASS – National Automotive Sampling System Update Training Instructor

Jan 16, 2002 – Seattle Harborview Medical Center Paramedic Training

March 4, 2002 – Shorewood High School – Force is with you outreach

March 15, 2002 – WA Traffic Safety Educator Conference

April 13, 2002 – SADD Conference – Students Against Destructive Decisions

April 25, 2002 – CIREN NHTSA Public conference – Traumatic Brain and Head Injuries

May 8, 2002 – WATAI – Washington Association of Traffic Accident Investigators Conference

May 15,2002 – Alaska Buckle Up Conference

May 23, 2002 – Oregon Health Division Quarterly Meeting

June 5, 2002 – Trauma Nurses Talk Tough Meeting

June 6, 2002 – Legacy Emmanuel Trauma Conference – Seaside, Oregon

June 17, 2002 – Harborview Medical Center Advisory Board Meeting

June 25.2002 – Alaska Injury Prevention Course – AK Department of Health

July 19, 2002 – Mason General County Hospital/Medic/Fire Rescue training

August 5, 2002 – American Driver and Traffic Safety Education Conference- Overland, KS

August 17, 2002 – National Traffic Safety Conference - Boise, ID

August 22, 2002 – CIREN Public Outreach Meeting, Seattle,WA

August 28-29, 2002 – Three Flags Law Enforcement Conference – Buckle up Oregon

September 19, 2002 – Peace Hospital – EMS Washington Southwest Region Training conference

October 9, 2002 – Washington State Patrol and Eastern WA Technician Law Enforcement training

October 25, 2002 – Oregon Department of Transportation Traffic Safety Conference

November 14-15, 2002 – Alaska statewide EMS Symposium Training

November 15, 2002 – Providence Hospital Grand Rounds, Anchorage AK

December 3, 2002 – CDC Injury Prevention Grand Rounds

December 5, 2002 – CIREN Public Meeting, NHTSA Washington D.C.

December 14, 2002 – Oregon Health and Science Trauma Center Conference

December 14, 2002 – Forensic Accident Reconstructionists of Oregon

Appendix 2.

Comments from people through out NHTSA Region X and selections from letters of appreciation for the outreach and training conducted by Seattle CIREN center

John Moffat, Director for the Washington Traffic Safety Commission and the Governor's Highway Safety Representative for the state of Washington stated:

"Your research has reached over 500 law enforcement officers in Washington State at over ten law enforcement training forums, and has brought an innovative and useful investigative element to reconstruction of collisions along with enhancing the ability of trained personnel to more effectively investigate collisions."

Jo Ann Moore, Highway Safety Manager of the State of Idaho wrote the following letter after Rob Kaufman was the keynote speaker for their statewide event.

Dear Rob:

Thank you so much for taking the time to help us make Idaho's fourth Start Smart... Buckle Your Belt Summit a huge success. Your presentation was very well received and we heard many positive comments, especially about the crash investigation information.

We believe that the motivation to enforce safety restraint laws in Idaho was significantly increased as a result of the summit. The participants appreciated hearing your comments and they are more aware of the value of their efforts to focus on safety restraint usage so that more Idahoans won't suffer needless tragedies.

Attendance included 110 law enforcement officers and 57 highway safety partners from various agencies and organizations. Thanks in part to you, the evaluations were extremely positive and indicate that participants learned a great deal at the summit and are eager to make even greater efforts to get all Idahoans buckled up.

Again, Mary Hunter, who coordinated the summit, and I thank you for contributing to the success of Idaho's fourth Start Smart... Buckle Your Belt Summit. You have been an outstanding asset to Idaho, not only by presenting at our summits, but also by being of assistance when we have called on your for technical expertise. Thank you for your contribution to our efforts to increase safety restraint usage in Idaho.

Sincerely,

JO ANN MOORE
Highway Safety Manager
Idaho Office of Highway Safety

Grangeville, Idaho police officer who attended a CIREN presentation at a state wide traffic safety conference stated:

" the presentation really brought home to me why supporting this effort to get the public to use seatbelts is so important." He later added, "the review of real world crashes clearly illustrated to me that low speed crashes can be serious and even fatal without the use of seatbelts."

Alaska Injury Prevention course attendees commented on their evaluations about the CIREN presentation and many stated that the material was excellent and increased their understanding of crash injury mechanisms and the importance of the continued effort to promote child restraint and seatbelt use.

Rosemary Nye from the NHTSA region X office stated:

"the Seattle CIREN team has done numerous presentations to hundreds, even thousands, of injury control traffic safety advocates around our region. This CIREN information has enhanced the advocates' knowledge on crash injury mechanisms and the Seattle team have continually been asked to return to many of the States in our region on an annual basis over the last four years.

Dr. Jerry Jurkovich, Trauma Director at Harborview Medical Center

"The CIREN program has been instrumental in bringing an awareness of engineering safety construction to the clinical care arena. The ability to reconstruct the forces involved in a crash help define the mechanism of injury, help explain the injury patterns, and hopefully will assist in the design of safer vehicles. The cooperative effort of engineers, surgeons, emergency medical personal, and crash reconstruction specialists has been brought about by the CIREN project, and the benefits of this new joint investigation should have great future dividends for trauma care and vehicle safety."

Carla Levinski Oregon Department of Transportation Occupant Protection Program Manager stated:

"Rob Kaufman from the Seattle CIREN team has delivered occupant kinematics presentations several times annually for the past four years in Oregon. He speaks once a year to police officers who work federal safety belt overtime enforcement, and has also spoken to Oregon Department of Transportation's annual statewide safety conference, Oregon Health Division's injury prevention program staff, and Legacy Emmanuel Hospital's trauma staff. Rob's enthusiasm, thorough knowledge, exceptional presentation skills, and continually updated materials have helped me (as a state safety belt program manager) to generate much greater awareness of the importance of "proper" restraint use and the importance of buckling all occupants. Rob relates his crash investigations to current policy issues (e.g., booster seat use) and walks you through crashes so you understand it is a real process with predictable outcomes based on restraint use."

Mary Moran, Alaska Highway Safety Office stated:

"we are grateful to have Rob Kaufman from the Seattle CIREN center give his CIREN presentation recently at our Buckle Up! Alaska event. The information about seatbelts and vehicle crash investigations was wonderful and the audience made up of police officers and emergency medical personnel found the material very informative. I can already think of several future occasions where his expertise could prove very useful in our state."

Appendix 3.

Summary of CIREN Public Meeting presentations done by Seattle team

October 1997, CIREN First Annual Meeting

Title: "Cervical Spine Injuries in Motor Vehicle Crashes"

Examined the injuries to the cervical spine occurring from all directions of force.

September 1998, CIREN Second Annual Meeting

Title: "The relationship of body weight and the risk of death in motor vehicle crashes"

Demonstrated an increased risk of injury and death to higher weight occupants in crashes. Formed the basis for a subsequent peer reviewed publication (See above).

September 1999, CIREN Third Annual Meeting, San Diego

Title: "Estimating the femur loads of occupants in actual motor vehicle crashes using frontal crash test data"

Examined a series of CIREN cases where the forces calculated for mid-shaft femur fractures were below the previously utilized threshold. Most of the occupants were bracing or braking at impact with the fractured leg. The muscle forces can produce 30 percent more force on the leg. Combining the muscle forces with the external force for the cases examined then produced the force needed to fracture the leg. Other factors involved the knees missing the bolster systems and striking a more stiff area on the instrument panels. Formed the basis for a subsequent peer reviewed publication (See above)

May 5, 2000 NHTSA CIREN public meeting – Theme: lower extremity injuries

Title: "Knee bolster contacts and leg fractures"

Examined a series of crashes showing the mechanisms associated with lower extremity fractures impacting the various knee bolster systems. Longitudinal intrusion of the instrument panel was directly related to increasing the axial load of the legs. Bracing of the leg, for instance on the brake, produced additional muscles forces which combined with the external force also produced fractures. Finally, many out of position lower legs in real world crashes missed the bolster systems striking very stiff areas on the instrument panel as compared to the perfectly placed crash dummies in crash tests that would strike the narrow region. CIREN data addressed the real world situations.

July 2000, NHTSA CIREN public meeting – Theme: Side Impacts

Title: "Injury Patterns in Side Impact: The Effects of Door Panel Stiffness and Geometry"

Examined a series of CIREN crashes showing the result of side door panel intrusion is directly related to body region injuries. For a near-sided occupant the lower door panel intrusion causes pelvic fractures, and the upper door panel intrusion may cause thoracic or head injuries. To further examine the near-sided occupant position it appeared the stiff armrest and geometry of the door panel was causing abdominal and chest injuries to the occupant. Selected door panels were mapped showing the stiffness and geometry. This showed that over three inches of penetration would occur to the abdomen in a relatively low speed crash from a stiff armrest. Seattle CIREN cases illustrated actual crashes showing the result of abdominal injuries from the stiff armrest.

March 2001, NHTSA CIREN Public Meeting – Theme: Offset Frontal Impacts

Title: "Offset Frontal Impact with SUV's and Corner to Corner (FLEE) Impacts"

Examined frontal offset collisions of passenger vehicles impacting SUVs that produced extensive longitudinal intrusion of the passenger vehicle compartments resulting in lower extremity, chest and head injuries. Further examined a series of critically injured occupants in passenger vehicles that involved in a frontal impact with an SUV with less than 14 inches contact at the bumper corners of both vehicles. This mechanism produced significant longitudinal and even laterally intrusion in the passenger vehicles. Many of these corner-to-corner impacts resulted in fatalities in the passenger vehicles.

July 2001, NHTSA CIREN Public Meeting – Theme: Getting the Word Out

Title: "Seattle CIREN Outreach in the NHTSA region X"

Discussed the various presentations created utilizing CIREN crash and medical research. Listed many of the target audiences and conferences where presentations had reached thousands of attendees in the northwest region. Presented an example presentation that mapped the injury mechanisms for all body regions. This presentation had been given to trauma care providers, traffic safety groups, and law enforcement professionals.

September 2001, CIREN Public Meeting – Theme: SUVs

Title: "SUVs involving rollovers, frontal offsets, and corner impacts called FLEE's"

Looked at a series of CIREN crashes showing how the weak roof structures of SUVs produced vertical intrusion causing neck and head injuries. Examined CIREN cases involving SUV frontal offset crashes that produced significant intrusion to opposing passenger vehicles especially in the corner to corner offsets.

December 2001, CIREN Public Meeting – Theme: Age-related Injuries

Title: "Children and Crashes"

Examined a series of children injured in motor vehicle crashes addressing suboptimal use of car seats as a potential safety item needing improvement. Through the use of MADYMO modeling, simulations were produced to show the forces acting on a 6-year-old child with and without the use of booster seats. The forces on the neck, abdomen and lumbar spine were greatly reduced when a booster seat was in place. Success stories were examined to show the effectiveness of utilizing child restraints correctly. Special attention was directed towards booster seats.

April 2002 CIREN Public Meeting – Theme: Head and Traumatic Brain Injuries

Title: "Head Injury Mechanisms and Preventive Measures"

Using the CIREN crash research, this presentation mapped critical head injury sources in motor vehicle crashes. Near-side impacts produced the most severe head injuries. Developed MADYMO model to examine HIC and G forces acting on the head when contacting a very stiff interior surface versus a possible padded interior surface. The reduction in HIC occurred dramatically with just minimal padding.

August 2002, CIREN Public Meeting – Seattle CIREN Center

Title: "Crash Injury Mechanisms in Vehicle Mismatch Collisions"

Examined three types of collisions involving the greater height of bumper frames on light truck vehicles (LTV) impacting the side and front of passenger vehicles. In side impact collisions, the LTV bumper height produced upper door panel intrusion causing injuries to an adult's thorax and a child's head. For frontal impacts, the override/underride of the bumper frames produce extensive crush to the grill and hood of the passenger vehicles. In most cases this produced longitudinal intrusion of the instrument panel causing injuries to the lower extremities, chest and even the head to the occupants in the passenger vehicle. Also, in the mismatch of bumper frame heights in the frontal impact the passenger frame makes contact to the tires and front axle of the LTV forcing these components rearward creating toe pan intrusion in the LTV. This produced serious foot and ankles injuries to the LTV front seat passengers. Biomechanical testing of cadaver feet showed that intrusion of the toe pan is directly related to foot and ankle injuries. All of these findings suggest the need for engineering changes in vehicles to provide greater side impact protection in passenger vehicles and to achieve greater harmonization between the bumper frame heights of all vehicles.